Proof of flight patterns of multi-layered balloon

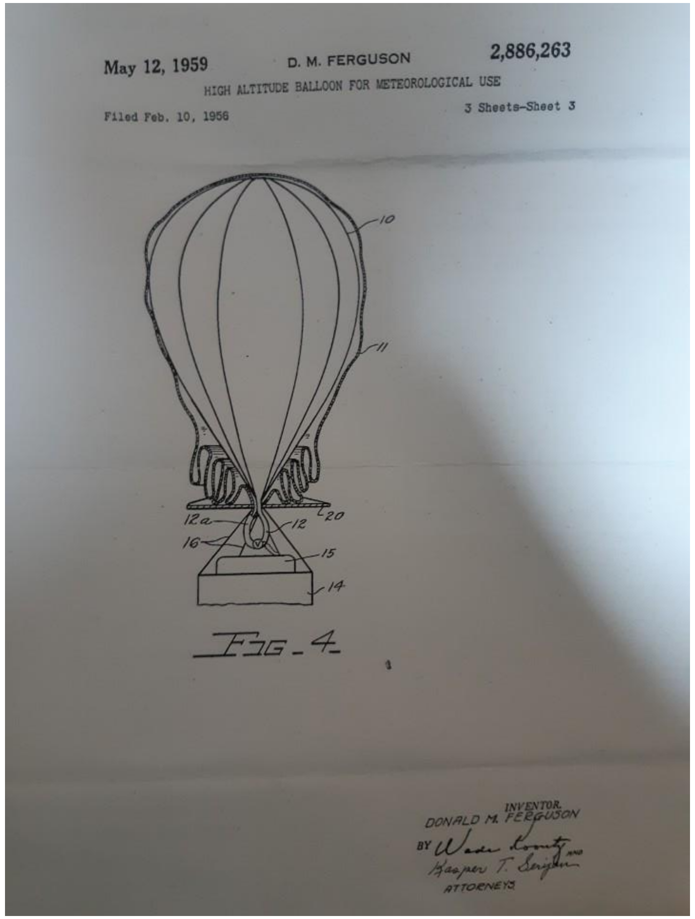
Min Hyeong Lee, Seoul National University

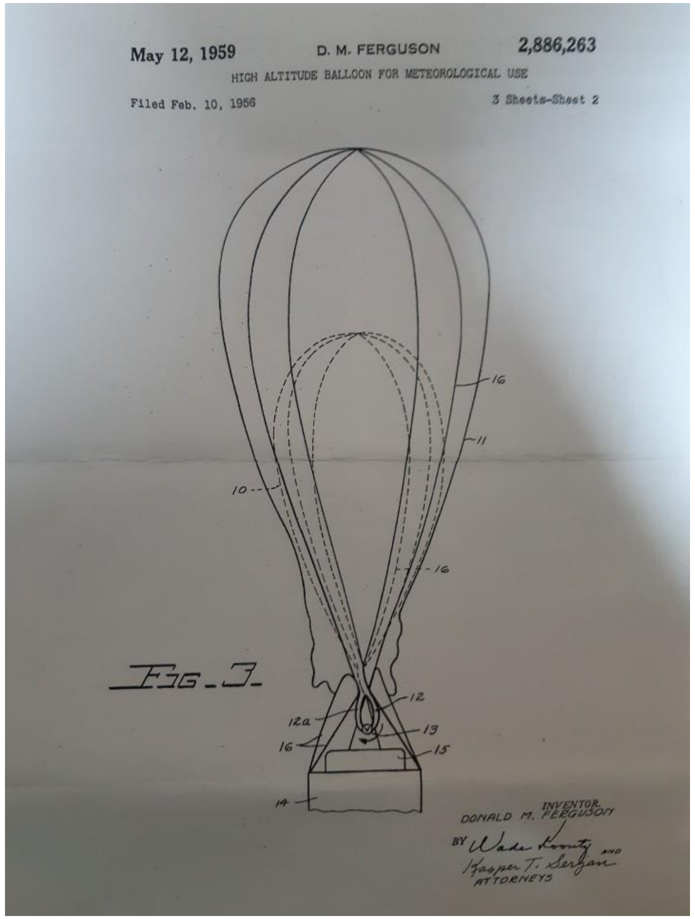
Near space balloon :

This is the balloon which is made of strong material as it can take its surface tension in very low pressure. It goes above stratosphere and bursts under approximately 30km.

Picture taken at 30 km using a 1,500 gram weather balloon

How can we make it go higher?

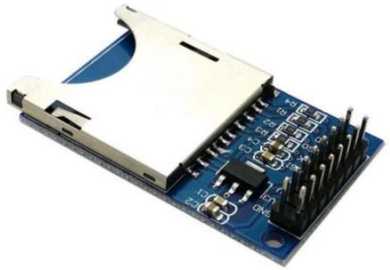




Concept of multi-layered balloon

MCU - Arduino

18B20 Arduino temperature sensor
Measurable range : -55 ~ 125℃



DM118 Arduino SD card module
Operating voltage: 3.3 ~ 5V

G-per , GPS with LoRa Network

Balloon Weight: 600g
Neck Diameter: 6-7cm
Inflated diameter: 148cm
Burst Altitude: 28000m
Burst Diameter: 5.7m
Payload: 250g
Helium Required: 1697 litres

Balloon Weight: 1200g
Neck Diameter: 8.5cm
Inflated diameter: 188cm
Burst Altitude: 31000m
Burst Diameter: 8.0m
Payload: 1000g
Helium Required: 3480 litres
The 1200g balloon parachute is nylon with a tyvek trim to strengthen the stitches.

Expected performance of balloon (600g, 1200g) used in this study

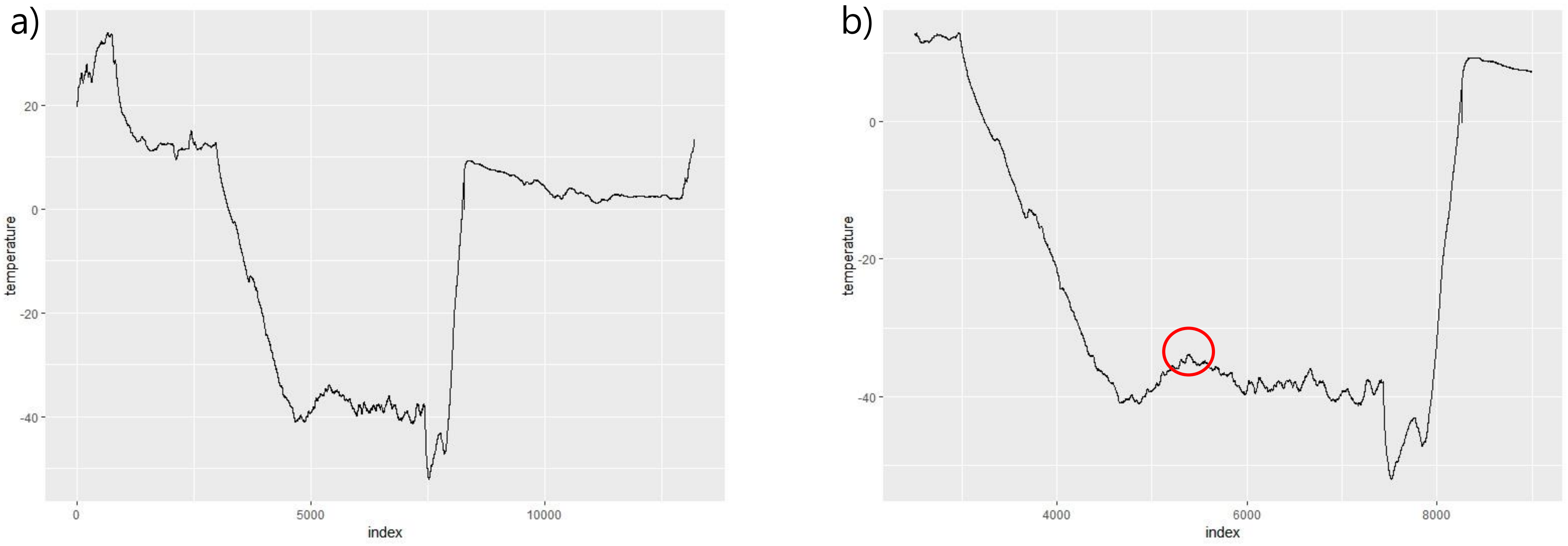


Fig 3. Plots of temperature record data
(a) Record of full data including data on non-flight time. (b) Plot of data on flight time extracted from raw data, and the high lighted part is the burst point, whose temperature is (-33 °C), and estimated altitude is 36km.

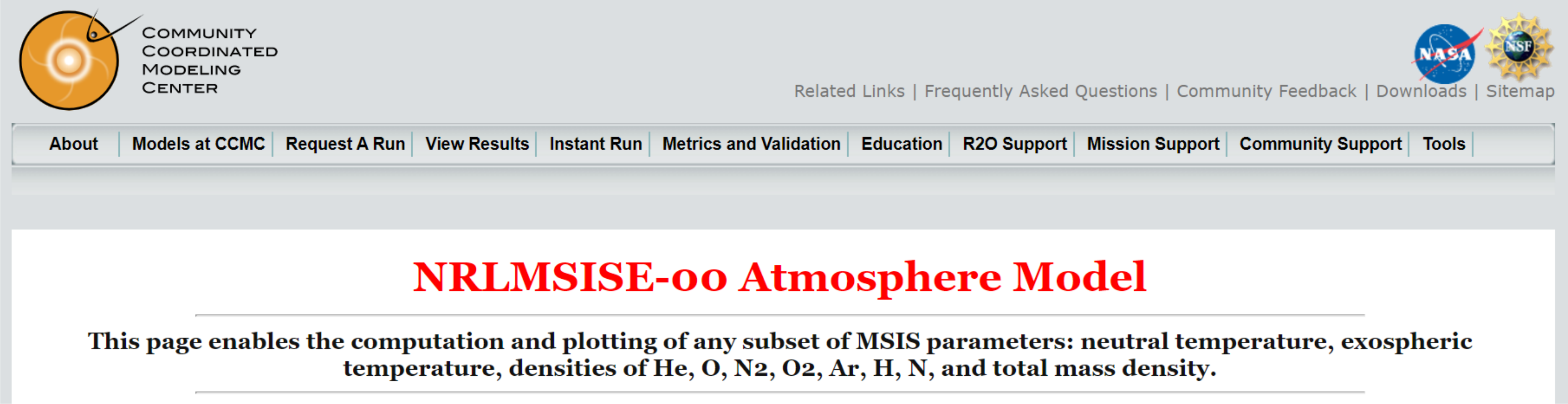


Fig 1. NRLMSISE-00 Atmosphere model
This atmospheric data table and tools for analysis of it produce various statistical results. It can be used via https://ccmc.gsfc.nasa.gov/modelweb/models/nrlmsise00.php.

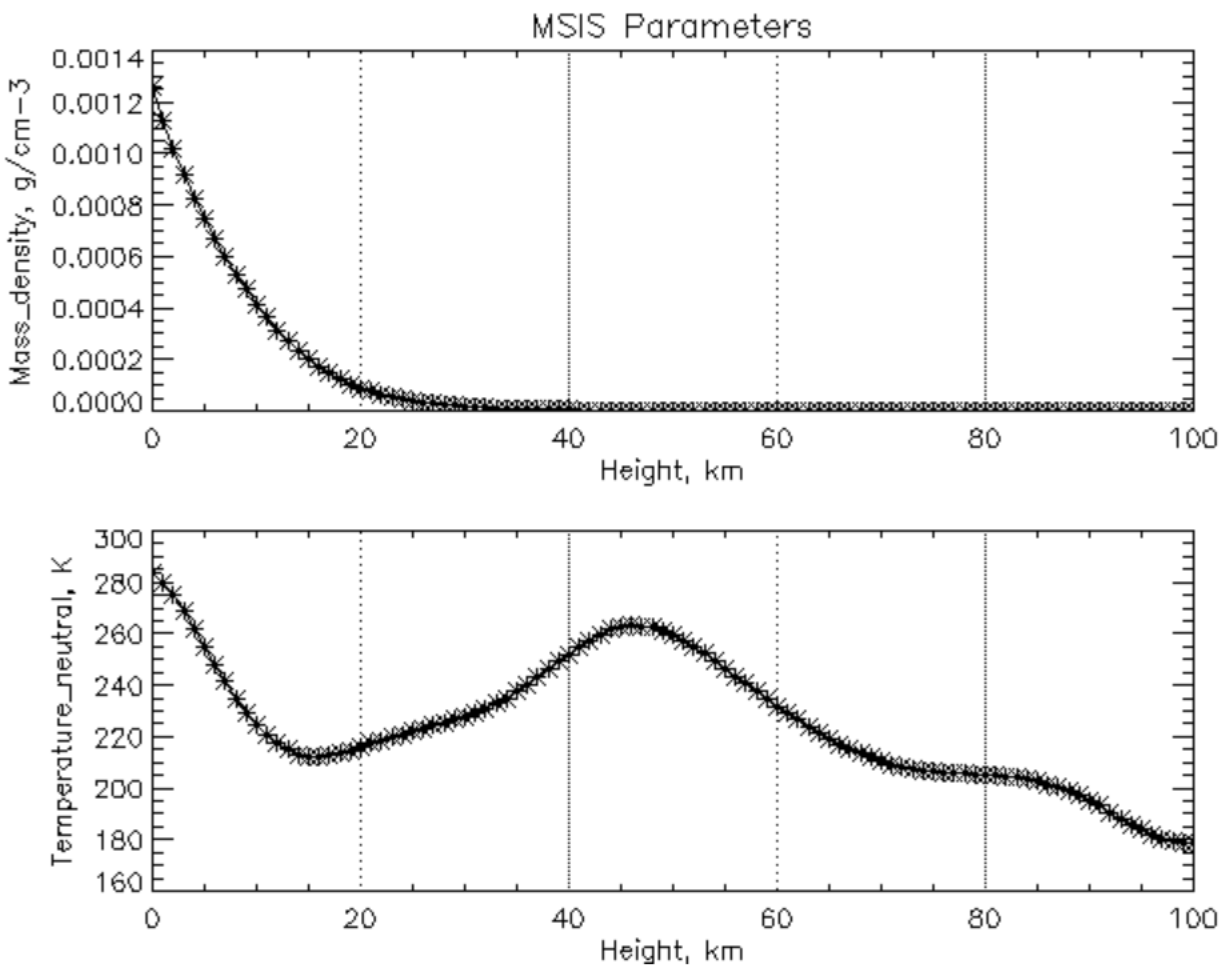


Fig 2. Expression of density and temperature by altitude from NRLMSISE-00
In the range of 0 to 100 km, the (a) density(g/cm-3) and (b) temperature(Kelvin, K) by height(km).

Calculate volume, in liter, for 1 mole by altitude

$$PV = nRT \qquad V = \frac{nRT}{P}$$

$R \approx 0.082$
$P = pressure\ in\ atm$
$T = absolute\ temperature(K = 273.15℃)$
$V = volume$
$n = mass\ in\ moles$

$Air's\ mass \approx 28.84g/mol$
$He's\ mass \approx 4g/mol$
$H_2's\ mass \approx 2g/mol$

Using ideal gas equation to calculate density

$$Altitude = 31km\ (Expected\ height)$$

$$V = \frac{1 * 0.082 * 227.65}{0.00995048} = 1876.02$$

$\text{Density(Air)} = 28.84\ \text{g}/1876.02\ \text{L}$
$=0.01537\ \text{g/L}$

$\text{Density}_i\text{(He)} = 4\ \text{g}/1876.02\ \text{L}$
$=0.00213\ \text{g/L}$

$\text{Density}_i(H_2) = 2\ \text{g}/1876.02\ \text{L}$
$=0.001\ \text{g/L}$

$\text{Density(Air)} - \text{Density}_i(He) = 0.0132$

Altitude = 36km (Observed height)

$$V = \frac{1 * 0.082 * 239.850}{0.00477983} = 4114.728$$

$\text{Density(Air)} = 28.84\ \text{g}/4114.728\ \text{L}$
$=0.007\ \text{g/L}$

$\text{Density}_i(\text{He}) = 4\ \text{g}/4114.728\ \text{L}$
$=0.000972\ \text{g/L}$

$\text{Density}_i(H_2) = 2\ \text{g}/4114.728\ \text{L}$
$=0.000486\ \text{g/L}$

$\text{Density(Air)} - \text{Density}_i(He) = 0.006$

$$Ratio = \frac{\{\mathrm{Density(Air)} - \mathrm{Density}_i(He)\}_{expected}}{\{\mathrm{Density(Air)} - \mathrm{Density}_i(He)\}_{observed}} = \frac{0.0132}{0.006} = 2.2$$

If both of balloons in two cases(multi layered and single layered) have the same volume (Liter, L) of lift up gas, this result of calculation means that multilayered balloon can take surface tension 2.2 times greater than single layered one.

Thank you

Min Hyeong Lee
minhyeong1022@gmail.com